THE INSTITUTE OF PHYSICS BULLETIN

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K. R. PILLING, *Clerk to the Governors.*

THE INSTITUTE OF PHYSICS

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Measurement and Interpretation of Surface Vibrations on Soil and Roads

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INTRODUCTION

Apparatus has been developed at the Road Research Laboratory which enables vibrations in the range 40 to 60,000 c/s to be propagated along the surface of soil or road constructions. The purpose of the present paper is to interpret the results in terms of the elastic properties and, where possible, the thickness of the construction.

So far, most of the work has been limited to experimental constructions, and the relevant data concerning thicknesses and types of material have therefore been available from laboratory records and experiments have also been made to determine the elastic properties of the materials. These data have enabled checks to be made of the validity of predictions from the vibrational experiments.

In the experiments, the wavelength of the vibrations is measured at specific frequencies and their phase velocity is derived from the product of their wavelength and frequency. For purposes of analysis, it has been found preferable to express the results as a graph relating phase velocity to wavelength and then to fit theoretical curves deduced from the propagation of plane waves in an equivalent type of layered construction : the thicknesses and elastic properties in the theoretical curves are adjusted to provide the best fit to the experimental results. This method of analysis is applied in this paper to the following types of construction :—

(*a*) Soil formations in which the elastic properties are uniform or have only slight variation with depth.

(*b*) Soil formations in which there is a distinct transition with a sudden increase in elastic modulus at a particular depth : this corresponds to a surface layer of lower elastic modulus than that of the underlying material. A typical example of this type of formation is a layer of soil overlying gravel or rock.

(*c*) Road constructions consisting of a surface layer with considerably greater elastic modulus than the underlying material. An example of this type of construction is a concrete slab laid directly on soil or on a deep granular base.

(*d*) Road constructions with a surface layer and an intermediate layer overlying a uniform medium : the material in the surface layer is taken to have an

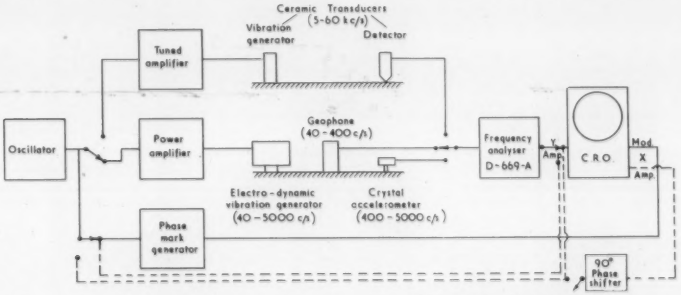

Fig. 1. *Schematic diagram of apparatus—switches set for first experimental technique*

elastic modulus which is considerably greater than in either of the two lower materials whilst the compressional wave velocity in the material of the intermediate layer is assumed to be less than that in the underlying material. This system is an idealized representation of a bituminous surfacing on certain granular base materials overlying clay soil.

There are many more combinations of properties within the three layer system which need to be considered and the analysis offered here represents a very limited contribution to what will ultimately be required.

EXPERIMENTAL TECHNIQUES

First Technique. A schematic diagram of the apparatus is shown in Fig. 1: different types of vibrator and pick-up are used for different parts of the frequency range.

Below 5000 c/s, the vibrations are produced by an electro-dynamic vibration generator for which Specifications for the generator, oscillator and power amplifier appear in Table I. The phase-mark generator squares and differentiates the waveform and ultimately produces a voltage pulse once per cycle. The voltage pulse is used to suppress the beam of the cathode-ray oscilloscope and so provide a reference mark which is fixed in relation to the phase of the vibrations produced by the generator.

The vibrations are received by a vibration pick-up and the waveform of the vibrations is displayed on the oscilloscope with the reference mark appearing as a short break in each cycle. In the present apparatus a geophone is used as the vibration detector at frequencies below 400 c/s, and a crystal accelerometer at frequencies between 400 and 5000 c/s; details of these pick-ups are given in Table I.

Table I. *Brief specification of apparatus*

Oscillator	Minimum frequency range : 30-60,000 c/s Accuracy better than ±1 per cent
Power amplifier	Output 50 watts in frequency range from 30 c/s to 5000 c/s
Oscilloscope	Single beam with amplifier response to at least 60 kc/s and provision for coupling to modulator grid
Electro-dynamic vibration generator	Modified Goodmans, Model 390A
Geophone	Pye. Sensitivity about 2V/in./s
Crystal accelerometer	Rochelle-salt bimorph.
Ceramic transducers	Hollow cylinders of Casonic III (barium titanate) 6 in. long × 1 in. O.D. × ½ in. I.D. on ⅛ in. thick diaphragm, giving resonant frequencies of about 6, 10, 14 and 24 kc/s. Also solid prisms of Casonic on ⅛ in. thick diaphragms, 1 in. square × 2 in., resonating at about 38 kc/s, and 1 in. × 1 in. × 1 in. resonating at about 57 kc/s.

Vibrations within the frequency range of 5-24 kc/s are obtained as specific resonances of a ferro-electric ceramic transducer in the form of a hollow cylinder. The ceramic transducer is driven by the oscillator through a tuned amplifier which has switched outputs, each tuned to one of the resonant frequencies of the transducer. The vibrations in the high-frequency range are detected by a hollow cylinder transducer which is identical with the generator; the specifications of the transducers are given in Table I. For convenience, the diaphragm of the receiving transducer has been tapered to a point to enable the shortest wavelengths, of about 2 in., to be located accurately.

In operation, the generator, which is either an electro-dynamic or a ceramic transducer, is placed on the road surface and the oscillator is tuned to the required frequency. The appropriate pick-up is moved progressively away from the generator and successive positions are found at which the vibrations are alternately in phase and in anti-phase with the fixed referen .e phase. These positions are indicated by the phase mark coinciding with a peak or a trough of the waveform display. The distances between successive positions are then equal to half wavelengths and, in practice, measurements are made over about four or more wavelengths in order to obtain a reliable average value. It must always be realized that the vibrator produces cylindrical waves so that the wavelengths occur at distances corresponding to the roots of a Bessel function and not at equal increments of distance as they do in plane waves. The discrepancy is most marked near to the vibrator and it is sufficiently accurate to regard the first wavelength as being 0·75 as long as the equivalent wavelength of plane waves with all subsequent wavelengths equal to that of plane waves. The phase velocity (c) is derived from the relation :—

$$c = n L \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

where n is the vibrator frequency
L is the average wavelength.

Second Technique. In this experimental technique the apparatus is basically the same as above except that provision is made for a circular time base on the oscilloscope. The apparatus is also shown in Fig. 1 and becomes operative when the three switches are thrown over to connect to the dotted part of the circuit. The display on the oscilloscope consists of a single bright spot whose position on the circular time base indicates the relative phase difference between the vibrations at the oscillator and at the pick-up. The circular time base makes one complete revolution per cycle of the applied vibrations so that the spot of the oscilloscope display moves once round the graduated circle as the pick-up moves one wavelength. The relation between the phase change (φ) and the distance moved by the pick-up (χ) is :—

$$\frac{\varphi}{2\pi} = \frac{\chi}{L} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

In practice it has been found convenient to move the pick-up away from the vibrator by fixed increments of distance and to measure the fractional change in wavelength as given by the movement of the spot around the graduated scale.

This technique is somewhat simpler and quicker to use than the first technique and has considerable advantages when the test length is so short that it is less than three wavelengths. In this case the incremental distance can be made as small as about 0·1 of a wavelength so that a larger number of results are obtained from which to obtain the average wavelength.

PROPAGATION OF SURFACE VIBRATIONS IN SPECIFIC TYPES OF SOIL FORMATION AND ROAD CONSTRUCTION

The nomenclature to be used in this section is as follows :—

Shear modulus of elasticity	G
Young's modulus of elasticity	E
Density	d
Compressional wave velocity	α
Shear wave velocity	β
Rayleigh wave velocity	γ
Height	H

with suffixes, 1, 2, 3, indicating respectively top layer, middle layer and semi-infinite base;

and applies to the road construction with two surface layers considered in (*d*). The simpler types of construction considered earlier in this section are merely degenerate cases. For example, the material with subscript 3 always represents soil which is assumed to have uniform elastic properties down to an infinite depth so that, in case (*a*) below the two surface layers are absent (i.e. H_1, $H_2 = 0$). The medium with subscript 2 in the intermediate layer is assumed to have elastic moduli less than that in medium 3 so that for case (*b*) below the surface layer is absent (i.e. $H_1 = 0$). The material subscript 1 in the surface layer is considered to have elastic moduli which are considerably greater than in either of the underlying media and in case (*c*) below the intermediate layer is absent (i.e. $H_2 = 0$).

(a) Soil having uniform elastic properties

Miller and Pursey (1955) have shown that a vibrator, on a circular base, operating normal to the surface of a semi-infinite elastic solid ($\mu = 0{\cdot}25$) radiates 67·4 per cent of the power as a surface wave. The surface wave here is a Rayleigh wave, which has its maximum particle displacement normal to the surface with a smaller particle displacement in the direction of propagation. The velocity (γ_3) of the Rayleigh wave is given by :

$$\gamma_3^2 = p^2 \quad \beta_3^2 = p^2 \quad \left(\frac{G_3}{d}\right) \quad \ldots\ldots\ldots\ldots \quad (3)$$

where β_3 is the velocity of the shear wave.
G_3 is the modulus of shear elasticity of the medium.
d is the density of the medium.

$\mu = 0{\cdot}2$	$p = 0{\cdot}911$
$\mu = 0{\cdot}3$	$p = 0{\cdot}928$
$\mu = 0{\cdot}4$	$p = 0{\cdot}942$
$\mu = 0{\cdot}5$	$p = 0{\cdot}955$

In the case of soil the value of μ is usually about 0·4 to 0·45 so that the surface wave travels about 5 per cent slower than the shear wave.

The shear and longitudinal waves produced by the vibrator are radiated into the entire volume of the medium and suffer much larger attenuation than the Rayleigh wave, which propagates near the surface. Consequently, the vibrations that are detected along the surface of a semi-infinite solid from a vibrator normal to the surface are almost exclusively Rayleigh waves.

Other theoretical work by Miller and Pursey (1954) indicates that if the vibrators perform rotary oscillations at the surface, the Rayleigh wave is absent and shear waves predominate.

Natural soil formations are rarely uniform with depth and this is reflected in the vibrational measurements by a variation in phase velocity with wavelength. However, the data are extrapolated to give the phase velocity (γ_3) at zero wavelength and the shear modulus (G_3) is calculated from the relation :—

$$G_3 = 2{\cdot}4 \cdot \gamma_3^2 d \times 10^{-4} \text{ lb/sq. in.} \quad \ldots\ldots\ldots\ldots \quad (4)$$

where d is the density of the soil (lb/cu. ft).

The shear modulus (G_3) given by equation (4) refers to the soil nearest to the surface which, under a road construction, is subjected to higher stresses than the deeper soil : this modulus is considered to be one of the properties required in calculations of stress distribution.

(b) Soil formations having a well defined surface layer with a lower shear elastic modulus than that of the underlying material

The nomenclature for this case is as follows :—

$$H_1 = 0$$
$$G_2 < G_3$$
$$\beta_2 < \beta_3$$
$$\gamma_2 < \gamma_3$$

Two types of vibration have been studied according to the orientation of the vibrator and pick-up to the surface of the soil. Rayleigh waves are produced when both vibrator and pick-up are perpendicular to the surface. Love waves are produced when the vibrator and pick-up are placed on their sides so as to operate parallel to the surface and transversely to the direction of measurement.

When vibrations of the Rayleigh wave type are propagated in a layered medium, their velocity depends upon the frequency of the vibrations and the thickness, density, and elastic properties of the strata. Theoretical results obtained for the principal mode of propagation of Rayleigh waves by Sezawa and Kanai are given in Fig. 2 from which it will be seen that at short wavelengths

Fig. 2. *Phase velocity of Rayleigh waves in a single layer over a semi-infinite medium* ($d_2 = d_3$)

the phase velocity approaches γ_2 : this enables the shear modulus of elasticity (G_2) of the surface material to be claculated as in equation (4). It will also be seen from Fig. 2 that the shape of the curve relating phase velocity to wavelength depends upon the thickness (H_2) of the layer and upon the ratio of the elastic moduli (i.e. $G_3 : G_2$). Differences in the density between the media would also introduce a further variable into the analysis. At wavelengths which are long in relation to the thickness of the layer, the phase velocity is asymptotic to γ_3 which, if attained, enables the shear modulus (G_3) of the underlying medium to be calculated.

For layered media in which the shear modulus increases with depth, the shear wave (horizontally polarized) gives rise to the type of surface waves known as Love waves. The theory is more tractable than for Rayleigh waves and, in the case of Love waves in a single surface layer, the frequency equation is as follows:

$$\tan \frac{2\pi H_2}{L}\left(\frac{c^2}{\beta_2^2}-1\right)^{\frac{1}{2}} = \frac{G_3}{G_2}\left(\frac{1-\dfrac{c^2}{\beta_3^2}}{\dfrac{c^2}{\beta_2^2}-1}\right)^{\frac{1}{2}} \quad \ldots (5)$$

where L is the wavelength of the vibrations
c is the phase velocity of the vibrations.

Asymptotic solutions of equation (5) show that for high frequencies, i.e. short wavelengths, the velocity of the Love waves approaches the velocity of shear waves in the medium of the surface layer (β_2). At low frequencies, the velocity of the Love waves approaches the velocity of shear waves in the base (β_3).

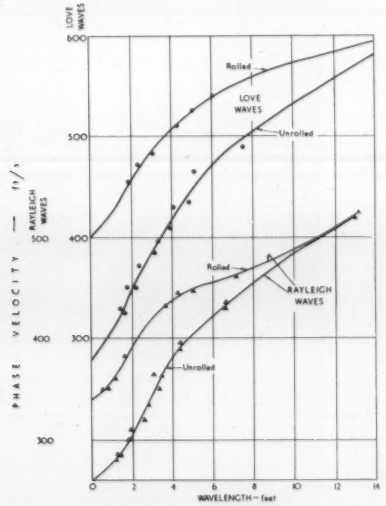

Fig. 3. *Variation of the phase velocity of Rayleigh waves and Love waves on sand before and after rolling*

Experimental results from the propagation of Rayleigh waves and Love waves have been obtained on several layered soils and some of the more interesting results are given in Fig. 3 for a sandy soil before and after compacting by a roller. On the unrolled site, measurements at different depths showed a marked transition in soil properties between 3 and 9 in. : for example, in-situ C.B.R. tests gave average values of 2·6, 13·2, 15·6 and 16·6 at depths of 3, 9, 15 and 21 in. A method of analysing the experimental results for Love waves using equation (5) has been discussed (Jones 1958) which indicated that the transition in elastic properties occurred at a depth of about 7 in. : the shear modulus of the unrolled surface layer was calculated to be 1700 lb/sq. in. After rolling, analysis of the Love wave data indicated a surface layer 8 in. thick in which the shear modulus was 4,000 lb/sq. in. Thus, rolling the sand produced compaction primarily in the top 7 to 8 in. of soil.

Analysis of the Rayleigh wave data gave values for the shear modulus of elasticity of the surface soil of 1,700 lb/sq. in. before rolling and 3,100 lb/sq. in. after rolling. The discrepancy in the estimation of the shear modulus from Love wave and Rayleigh wave data after rolling was considered to be due to anisotropy produced by the compaction of the sand. It is also possible to analyse the experimental results for the Rayleigh wave data using the curves of Fig. 2 so as to calculate the thickness of the surface layer : the results are in good agreement with similar deductions from the Love wave data.

Other cases of the propagation of vibrations in clay soil overlying gravel have been studied in which the thickness of the clay layer was about 5 ft. Estimation of the thickness from the Love wave data gave extremely good agreement with the actual thickness as measured at boreholes (Jones 1958). In some of these experiments, there were two distinct types of vibration present in the Rayleigh waves of which the one corresponding to the Principal Mode predominated nearer the vibrator. Once this wave had decayed, a second faster wave was obtained which was attributed to another mode of propagation of the vibrations (Jones 1958).

(*c*) *Road constructions with a single surface layer of considerably higher elastic moduli than the underlying material*

In this case :—

$$H_2 = 0$$

$$\alpha_1 > \beta_1 > \alpha_3 > \beta_3$$

Under these conditions, surface vibrations of the Rayleigh wave type can only exist for a limited range of phase velocity (c) given by :—

$$\beta_3 > c > \gamma_3$$

The solution for c within this range is obtained from an eight order determinant (Stoneley 1954) and the computation is somewhat laborious. At very long wavelengths the phase velocity will approach γ_3 but it is difficult to predict what will happen when the phase velocity becomes comparable with or exceeds β_3. In order to simplify the problem it has been assumed that,

once the phase velocity exceeds β_3, the underlying material may be treated as a liquid. This is not a particularly drastic assumption since the Poisson's ratio of most soils is of the order of 0·45 so that α_3 is 5 to 10 times β_3. The most convenient form for the solution of the problem of the propagation of plane waves in a plate resting on a liquid has been given by Press and Ewing (1951) and the analysis for the propagation of flexural waves has now been obtained (Jones unpublished). The results of the analysis are given in Fig. 4. It will be seen that the phase velocity/wavelength curve has at least one discontinuity which occurs near the velocity of compressional waves (α_3) in the underlying medium. Above α_3, the results are generally in very good agreement with the solution obtained by Lamb (1916) for the propagation of flexural vibrations in a free plate. As the phase velocity approaches α_3, the discrepancy between the phase velocity in the free plate case and in the case of an underlying liquid becomes greater and there is also a considerable increase in attenuation of vibrations. Below α_3, the branch of the curve denoted by (*b*) is expected to account best for the propagation of the vibrations. The short wavelength part (*a*) of this branch represents a type of vibration which has its maximum amplitude at the interface between media 1 and 3 and which will not be found experimentally in the presence of the surface vibrations characterized by the upper branch. The analysis does not give any indication of the nature of the transition between part (*b*) of the curve and the Rayleigh wave solution (*c*) for the propagation of very long waves and phase velocities less than β_3. It is considered likely from theoretical considerations that there will be a discontinuity near β_3.

The theoretical analysis indicates that over most of the frequency range there is likely to be more than one type of vibration being propagated and the question arises as

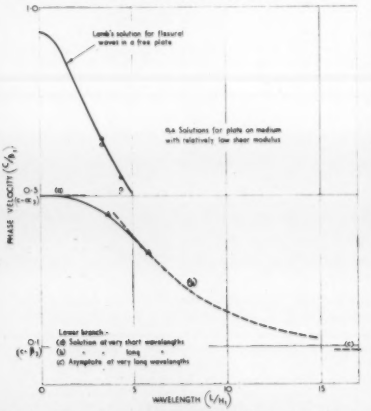

Fig. 4. *Theoretical relation between phase velocity and wavelength for a plate overlying a medium with relatively low shear modulus* ($\beta_1 = 2\alpha_3 = 10\beta_3$; $d_1 = d_3$; $m_1 = \frac{1}{4}$)

to how this will affect the experimental observations. Van der Poel (1951) has shown that the wave with the greatest amplitude will be detected and that it is only when there is a near equivalence in amplitude that destructive interference occurs. Thus, the discontinuity

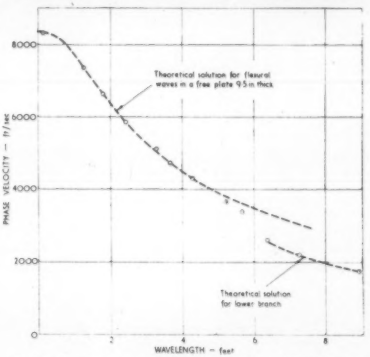

Fig. 5. *Results from concrete slab nominally 9 in. thick laid on well compacted hoggin*

between the upper and lower branches of Fig. 4 is expected to be characterized experimentally by a narrow range of frequencies within which there will be strong interference and ill-defined propagation of the vibrations.

It is only rarely that a practical road construction approximates to the case of the single surface layer considered above. One example is that of a concrete slab laid directly on soil or on a thick granular base. The results given in Fig. 5 were obtained from experiments on a concrete slab, nominally 9 in. thick, laid on a well compacted hoggin base 2 ft thick. The theoretical curves shown on Fig. 5 have been calculated from the following data :—

1. The value of γ_1, for concrete has been taken as 8,350 ft/sec : this is fixed by the experimental results at about 60 kc/s (i.e. $L = 0{\cdot}139$ ft).

2. Poissons ratio for concrete has been taken as 0·25. This value was deduced from γ_1 in conjunction with the compressional wave velocity α_1, measured by an ultrasonic pulse method (Jones and Gatfield 1955) at the surface of the slab.

3. The ratio of the densities of the hoggin to concrete was assumed to be 2 : 3.

An excellent fit with experimental results is given in Fig. 5 when the thickness is assumed to be 9·5 in. Subsequently, two cores were drilled from the slab and indicated thicknesses of 9·55 in. at the centre and 9·85 near the corner.

It will be seen from Fig. 5 that the experimental results at wavelengths of 5·4 and 5·65 ft deviated from the theoretical curve for flexural vibrations in a free plate. This deviation is predicted by the theory given earlier and indicates that the phase velocity at these wave-

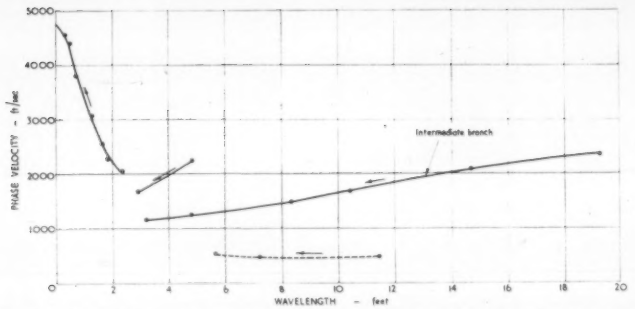

Fig. 6. *Experimental results from a road construction consisting of 4 in. rolled asphalt on 13 in. (approx.) sand base on clay subgrade*

lengths is just above the velocity α_3 of compressional waves in the hoggin (about 3000 ft/sec).

(d) Road construction with a surface and an intermediate layer

In the case to be considered below the magnitudes of the phase velocities were as follows :—

$$\alpha_1 > \beta_1 > \alpha_2 > \beta_2 \approx \beta_3$$

This particular problem was analysed because of some very anomalous results obtained in experiments on a section consisting of an asphalt surfacing 4 in. thick on a sand base about 13 in. thick overlying clay. The experimental results are given in Fig. 6 in the form of the phase velocity/wavelength curve. Experimentally, the measurements commenced at a frequency of 40 c/s and the frequency was increased by increments up to 13,750 c/s. At frequencies of 40, 70 and 90 c/s the phase velocities were 460,462 and 504 ft/sec. as indicated on the lowest branch of Fig. 6. A further increase of frequency to 120 c/s caused a very large increase in wavelength and a jump in the phase velocity to 2,320 ft/sec. Subsequent increases in frequency to 360 c/s produced decreasing phase velocities and gave rise to what will be called the intermediate branch of the phase-velocity/wavelength curve. Between 360 c/s and 460 c/s there was another jump in phase velocity from 1,150 to 2,220 ft/sec. followed by a decrease to 1,680 ft/sec. when the frequency increased to 575 c/s. At frequencies higher than 875 c/s the results gave the well-defined upper branch.

The intermediate branch of the curve of Fig. 6 bears a strong resemblance to the dispersion of longitudinal waves in a liquid layer on a liquid substratum (Pekeris 1948) and it was considered that this branch represented longitudinal waves in a form of wave-guide. For this to be possible requires that the velocity of compressional waves in the sand should be about 1,000 ft/sec. and should be less than the velocity of compressional waves in the clay (about 2,300 ft/sec.). Samples of the sand and clay were moulded into specimens suitable for test by the ultrasonic pulse method (Jones and Gatfield 1955) and it was found that the pulse velocities were consistent with these values.

The theoretical analysis has been carried out treating the sand and clay as liquids (Jones unpublished). The results of the analysis are therefore not applicable when the velocities become comparable with β_2 or β_3 but it is expected to apply to phase velocities which exceed β_2 or β_3 by 25 per cent or more. Computations have been made for ratios of wave velocities and thicknesses consistent with the experimental construction (i.e. $\alpha_1 = 2\beta_1 = 4\alpha_3 = 10\alpha_2$, $d_1 = 1{\cdot}2\ d_2 = 1{\cdot}1\ d_3$, $H_2 : H_1 = 3$ and 4). The results are given in Fig. 7 and show clearly the various branches of the curve found experimentally in Fig. 6. Direct comparison between experimental and theoretical results shows that the main deviations are at long wavelengths on the intermediate branch and at the long wavelength on the lowest branch. The deviations on the intermediate branch may be due to variations in the properties of the clay with depth or to the sand layer being thicker than allowed for in the analysis. In practice, the sand layer had a thickness varying from 9 to 23 in. over the 200 ft length of section and measurements were made over a length for which the nominal thickness was from 10 in. to 17 in.: this variation in thickness along the line of measurement may also have influenced the results. The phase velocities along the lowest branch of the curve were becoming comparable with the velocity of shear waves in the clay and sand so that deviations were to be expected here because of the inadequacy of the analysis.

The factors which can be positively identified from the experimental data are :—

(1) The velocity of shear waves in the asphalt at a frequency of about 30,000 c/s ; this enables the shear modulus of elasticity of the asphalt to be estimated.

(2) The thickness of the asphalt layer.

(3) The velocity of compressional waves in the sand.

In addition an estimate can be obtained of the velocity of compressional waves in the clay.

One item of practical interest has been to deduce changes occurring in the properties of the sub-base of this construction under traffic. It is the intermediate branch of the phase velocity/wavelength relation which

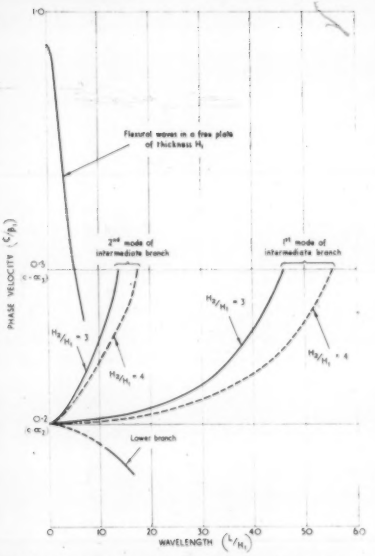

Fig. 7. *Theoretical solutions for the propagation of vibrations in a system with two surface layers* ($\alpha_1 = 2\beta_1 = 4\alpha_3 = 10\alpha_2$; $d_1 = 1{\cdot}2\ d_2 = 1{\cdot}1\ d_3$)

provides this data and experimental results were obtained initially and about 7 months and 13 months after the road was opened to traffic. The value of α_2 increased from about 1,100 to 1,450 ft/sec. during the winter and spring whilst there was a further increase to about 1,950 ft/sec. during the summer. These increases were due to compaction of the sand sub-base by the relatively high stresses generated below the thin construction. It is interesting to observe that there was a greater incremental increase during the summer months when the effective elastic moduli of the surfacing were relatively low so that the imposed stress was higher than in the colder period of the year.

ACKNOWLEDGEMENT

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Some changes and current trends in secondary education

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[Based on a talk given on April 21, 1960, to the conference of the Institute's Education Group and Midland Branch.]

THERE have been many changes in the last few decades in the courses offered at universities and technical colleges for training scientists and engineers to keep abreast of the demands of our scientific age. In a similar manner attention has been focused on our schools and change again is the order of the day. This is not change merely for the sake of change, but a definite endeavour to fit pupils when they leave school to use their talents to the fullest extent in the new sphere in which they find themselves, i.e. industry, part-time employment and education or full-time further education. We all know that if a school wishes to build a reputation for distinction in games or athletics we must begin with the training at an early age, and in like manner, for success in the academic field it is vital that the right grouping of subjects, methods of study and mental disciplines are developed in schools.

The changes at the present time arise from different pressures due to:—

(*1*) Dissatisfaction with the methods of selection for pupils to take the more academic type of course usually associated with the grammar school. This may be due to the suspect nature of the qualifying examinations depending on "intelligence testing," and in part to social grievance.

(*2*) Dissatisfaction with the range of subjects and the allocation of time to them which can be conveniently dealt with under the heading "curriculum reform."

(*3*) Dissatisfaction with external examinations and their syllabuses, i.e. reforms in Ordinary and Advanced level G.C.E. and Open Scholarship examinations from the academic side and reforms in the National Certificate examinations associated with industry.

(*4*) Dissatisfaction with the "end-product." We hear so much and read in the newspapers of some sixth-formers who cannot express themselves clearly and have no real knowledge beyond the facts of two or three Advanced level subjects they have studied, and at the other extreme, pupils leaving the modern school who are illiterate.

If we deal with these four items we shall see how suggested solutions will contribute to others which are the title of this discussion.

Methods of selection are not really our immediate concern, but they do govern the end product. Hitherto, the eleven plus or Q.E.S.S. has been quite successful for the bright pupil, but there have been many disquieting failures in the broad band of average pupils. This age is too early to decide a child's future course, i.e. whether more academic studies should be pursued or learning tackled in a practical or project manner. Hence the comprehensive experiment or its modification; e.g. in Leicestershire the grammar school of 700 pupils fits end-on to the four feeder high schools (formerly modern schools with 2,000 pupils in all) and all parents who wish their children to stay to 16 or 18 years of age can do so. A wide variety of courses offered with the possibility of transfer horizontally. For very bright pupils transference to the high school from junior school is at 10 instead of 11 and all pupils stay three years in a high school. They are streamed to take three types of course—normal grammar (academic), technical high and modern (taken to 16).

There is already a *vast* improvement in the reaction of the public, the teacher and pupil to this new set up. There is little early leaving and no frustration for pupil or parent and a wonderful encouragement for the former modern school teacher, who now gets a share of the best pupils.

PROBLEMS OF CURRICULUM

Lord James' so called "Law of the Conservation of the Curriculum" operates here; you cannot put in any more subjects without removing some already there. Questions arise such as, what subjects shall be taught, for how long and to what standard? The answer to these questions governs the end product. For the bright pupil the base should be broad and the child of 11 introduced to a range of subjects such as English Language and Literature, History, Geography, Scripture, French and Latin, Science and Mathematics and cultural subjects such as Art, Music and Handicraft, as well as Physical Education. At the age of 14 this range of academic subjects should be reduced to about eight which should be taken to Ordinary level by our brightest pupils.

There are many variations, but at Hinckley we arrange a basic core of subjects (English, French, Mathematics and add four others, one from each of four groups). This gives a wider choice than most of us here to-day had when we were at school. The following tables illustrate the curriculum and options. There are 40 periods in the week, each of 40 minutes.

For the technical high school type, a more limited grouping should be studied, with emphasis on the practical approach. An even more reduced range of subjects for the weakest pupils should be built around the

HINCKLEY GRAMMAR SCHOOL: PROPOSED SCHEME WHEN LEICESTERSHIRE PLAN FULLY OPERATIVE

	BASIC	OPTIONS
Sixth Form Sc2	Eng. (3), Fr./Ger. (2), R.I. (1), P.E. (1), Games (2), Hist. of Science (2), General (1)	Physics (8) { Pure Maths (8) + App. Maths (8) / or Maths (8) + Chem. (8), or Geog. (8) / or Chem. (8) + Bio. (8) / or Maths (8) + Engin. Draw. (5) + Metal (3) }
Sixth Form Sc1	Eng. (3), Fr./Ger. (2) R.I. (1) P.E. (1), Games (2), Hcft./D.Sc. (2), General (1)	Physics (8) { Pure Maths (8) + App. Maths (8) / or Maths (8) + Chem. (8) or Geog. (8) / or Chem. (8) + Bio. (8) / or Maths (8) + Engin. Draw. (5) + Metal (3) }
Sixth Form Arts 2	R.I. (1). (1), Games (2), Hist. of Science (2), General (1)	8 periods each of 3 of: English; French; R.I.; German; Hist.; Latin; Geog.; Music; Art.
Sixth Form Arts 1	R.I. (1), P.E. (1) Games (2). Hcft./D.Sc. (2) General (1)	8 periods each of 3 of: English; French; R.I.; German; Hist.; Latin; Geog.; Music; Art.
4th and 5th Year *Special Academic Streams*	Eng. (5), Fr. (5), Maths (5), P.E. (1), Games (2) R.I. (1), Music (1)	5 periods of 1 subject from each group: Group 1: Latin, Chem., Bio., Physics. Group 2: History, Geog., Bio., Hcft./D.Sc. Group 3: Physics, Germ., R.I., Music. Group 4: Hist., Geog., Chem., Art., Gk.
4th and 5th Year *Normal Academic Streams*	Eng. (5), Maths (5), Hist. (3), Geog. (3), Chem. (3), Bio. (3), R.I. (1), Phys. (3), Fr. (5), P.E. (1), Games (2)	6 periods of Art or Music or Hcft./Dom. Sci.
4th and 5th Year *Technical and Commercial Streams*	Eng. (5), Maths (5), Hist. (3), Geog. (3), R.I. (1), P.E. (1), Games (2)	5 periods of Fr. or Engin. Draw.; 6 periods of Art or Music or Hcft./D.Sc.; 9 periods to allow: *Either* Commerce (6) + Gen. Sci. (3) *or* Chem. (5) + Phys. or Bio. (4) *or* Chem. (3) + Phys. (3) + Bio. (3)
4th and 5th Year *Non-academic Streams*	Eng. (5), Maths (5), Hist. (4), Geog. (4), R.I. (1), P.E. (1), Games (2)	4 periods of Mus. or Hcft./D.Sc. 5 periods of Eng. Draw. or Art (3) + Commercial English (2) 3 each of Phys., Chem., Bio., or 6 Commerce + 3 Gen. Sci.

HIGH SCHOOLS

3rd Year *Academic Streams*	Eng. (5), Fr. (4), Lat. (4), Maths (5), Hist. (3), Geog. (3), Phys. (3), Chem. (3), Bio. (3), R.I. (1), P.E. (1), Games (2)	3 periods of Art or Hcft./Dom. Sci.
3rd Year *Non-academic Stream*	Eng. (9), Maths (5), Hist. (3), Geog. (3), Art (2), Mus. (2), Hcft./D.Sc. (5), Sci. (6), R.I. (1), P.E. and Games (4)	
2nd Year *Academic*	Eng. (5), Fr. (4), Lat. (4), Maths (5), Hist. (3), Geog. (3), Phys. (3), Chem. (2), Bio. (2), Art (2), Hcft./D.Sc. (2), R.I. (1), Music (1), P.E. (1), Games (2)	
2nd Year *Non-academic*	Eng. (10), Maths (5), Hist. (3), Geog. (3), Art (2), Mus. (2), Hcft./D.Sc. (4), Sci. (6), R.I. (1), P.E. and Games (4)	
1st Year *Academic*	Eng. (6), Maths (6), Hist. (3), Geog. (3), French (4), Latin (4), Art (2), Music (1), Hcft./D.Sc. (2), Phys. (2), Chem. (2), R.I. (1), P.E. and Games (4)	
1st Year *Non-academic*	Eng. (10), Maths (6), Hist. (3), Geog. (3), Art (2), Music (2), Hcft./D.Sc. (2), Sci. (6), R.I. (2), P.E. and Games (4)	

DETAILS OF OPTIONS IN 4TH AND 5TH YEAR SPECIAL ACADEMIC STREAMS

Compulsory Subjects: ENGLISH (5 periods), FRENCH (5), MATHS (5), P.E. (1), R.I. (1), GAMES (2), MUSIC (1).

Options: One subject (5 periods) from each of the following groups:

A	B	C	D
Chem.	Hist.	Physics	Chem.
Bio.	Geog.	Ger.	Art
Latin	Bio.	R.I.	Hist.
Physics	Hft./Dom. Sci.	Music	Geog.
			Greek

The same subject cannot be taken in two different groups.

Some typical combinations under this scheme:

For the pupil proceeding to 6 ARTS

(1) English; French; Maths; Latin; History; German or Physics; Geography or Biology or Chemistry.
(2) English; French; Maths; Latin; German; and two from History, Geography, Biology, Chemistry/Greek.
(3) English; French; Maths; Latin; Greek; History or Geography or Biology; Physics or German or R.I. or Music.
(4) English; French; Maths; History; Geography; and one from Chem./Bio./Latin/Phys. and one from Ger./Mus./R.I./Phys.
(5) English; French; Maths; Music; Art; Chem. or Bio. or Phys. or Lat.; Hist. or Geog. or Bio. or Hft./Dom. Sci.

For the pupil proceeding to 6 SCI.

(1) English; French; Maths; Phys.; Chem.; Bio.; Lat. or Hist. or Geog. or Art or Hft./Dom. Sci. or Greek.
(2) English; French; Maths; Phys.; Chem.; Hist. or Geog. or Hft./Dom. Sci.; Lat. or Hist. or Geog.
(3) English; French; Maths; Phys.; Bio.; Hist. or Geog. or Art; Lat. or Hist. or Geog.

For the pupil undecided between ARTS and SCIENCE:

(1) English; French; Maths; Lat.; Phys.; Hist or Geog. plus Bio. or Chem.
(2) English; French; Maths; Lat.; Bio.; German and Chem., or Phys. and Hist. or Geog.

For girls wishing to specialize in Dom. Sci.:—Dom. Sci.; Eng.; French; Maths; Chem.; Phys. or Ger. or R.I. or Mus.; Bio. or Art or Hist. or Geog. or Lat.

For pupils with special interest in Hcft.; Art or Music:

(1) English; French; Maths; Hcft.; Art; Chem. or Phys. or Bio. or Lat.; plus Phys. or German or R.I. or Music.
(2) English; French; Maths; Music; Art; Chemistry or Bio. or Lat. or Physics; plus Hist. or Geog. or Bio. or Hcft./Dom. Sci.

Some subjects which have been omitted by the pupil in the Main School can be studied in the Sixth Form, e.g. Foreign Languages, Practical Subjects, etc.

KEY:—Eng. (English Language and Literature), Fr. (French), Ger. (German), R.I. (Scripture), P.E. (Physical Education), Hist. (History), Lat. (Latin), Gk. (Greek), Phys. (Physics), Chem. (Chemistry), Bio. (Biology), Hcft. (Handicraft), D.Sc. (Domestic Science), Engin. Draw. (Engineering Drawing), Geog. (Geography).

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objective of "numeracy and literacy." (Crowther Report.)

Finally, the whole curriculum should be geared to what will be required by pupils proceeding either to Sixth Form (Advanced Level), technical colleges or craft schools linked with part-time education.

SYLLABUSES

Here we have the thorny problem of tradition associated with the matriculation and faculty requirements. In the syllabus recommendations of both the Science Masters' Association and the Gulbenkian Foundation, the desire is to reduce the content of the syllabuses in science for Ordinary and Advanced Levels by pruning those parts which are somewhat out of date, or too detailed, and by saving of time to devote a third of the Sixth Form time to unrelated subjects which will enhance the "literacy" of our students. There is much to be said for the "General Paper" and also for a modified Advanced Level with a compulsory essay type of answer for at least one question in each paper. If the syllabus demands this, all the schools will respond. I do not propose to deal with the syllabus in detail but I think more pupils should stay for a third year in the Sixth Form to digest the two year Advanced Level course, read around it and slightly beyond, especially those taking Scholarship papers.

What other associated subjects should be taken at Advanced level by Physicists is a matter of equal importance, e.g. Mathematics (Combined) or as Separate Subjects, Mathematics and Theoretical Mechanics. If the latter, then Ordinary level is of great importance as there should be evidence of some knowledge of Chemistry and Biology. There is much scope in the applied fields of these subjects where Mathematical Physicists will be wanted. I would also make a plea of Advanced Level Engineering Drawing or Chemistry for those taking the Combined Mathematics paper.

THE END PRODUCT

What should we look for in our end product, whether University or Technical College ?

(1) Enthusiasm for the subject and an indication of the discipline required to succeed.
(2) A background of literacy which will show that the student can explain, in a non-technical way, his own speciality.
(3) Reasonably wide interests beyond Science, together with an understanding of the economy of this country.
(4) A desire to serve rather than profit by what he has achieved. This is really linked with a Christian, rather than a materialistic view of Society.

Finally, there is the question of which type of student should go to the university and which to the Colleges of Advanced Technology. In the past, too many have opted for the former. I consider more should attempt diploma rather than degree courses and more should go via the thick and thin sandwich courses—others direct to the technical colleges. The close link with industry is an invaluable stimulus to this type of student. Again, some of our Sixth Form pupils are keen to go directly into industry on completing their Advanced Level. These are the students most likely to succeed in the Diploma of Technology. Their career is often clearly marked and they feel less dependent on the State or their parents for maintenance and tuition fees. This sense of purpose and direction together with independence is clearly discernable before they leave school.

Notes and News

Proceedings of the final General Meeting of the Institute

An Extraordinary General Meeting of the Institute was held on Tuesday, July 5, 1960, in the Institute's House, 47 Belgrave Square, London. The President, Sir George Thomson, was in the Chair. About 50 Fellows and Associates were present and the Secretary read the notice convening the meeting.

The President mentioned that the first part of the meeting replaced the Annual General Meeting of the Institute which had been originally convened for 5 p.m. that day. The Annual Report of the Board and the Annual Accounts were unanimously adopted.

The President then reminded the meeting that the three Special Resolutions before it were concerned with the winding up of the Institute and the handing over of its property and its funds to the amalgamated body, The Institute of Physics and The Physical Society, in accordance with the Scheme of amalgamation which had been approved by the vast majority of members last year.

The President then moved and Dr. F. A. Vick (Honorary Secretary) seconded each of the following resolutions, each of which was carried unanimously :

Resolution 1. THAT the Company incorporated under the Companies Act, 1948, on the 17th day of May 1960 and known as The Institute of Physics and The Physical Society, having objects similar to the objects of the Institute and prohibiting the distribution of its income and property amongst its members to an extent at least as great as imposed on the Institute by Clause 4 of its Memorandum of Association, is an institution to which the Institute may on a winding up or dissolution transfer its assets.

Resolution 2. THAT upon the liquidation of the Institute proposed by the next following resolution the remaining assets of the Institute after satisfaction of all debts and liabilities be paid or distributed to The Institute of Physics and The Physical Society.

Resolution 3. THAT the Institute be wound up voluntarily and that Ernest William Coleman of Messrs. Knox, Cropper, Gedge & Co. of Spencer House, South Place, E.C.2, and Herbert Raphael Lang, Secretary of The Institute of Physics of 47 Belgrave Square, London, S.W.1, be appointed liquidators for the purposes of such winding up.

The meeting concluded with votes of thanks to the President, Honorary Officers and members of the Board, to the Executive Officers and staff, to the Branch and Group Honorary Officers, and to those who had allowed the use of their rooms for various meetings in different parts of the country during the year.

Final General Meeting of the Physical Society

At an Extraordinary General Meeting of The Physical Society held on July 5, 1960, at 1 Lowther Gardens, London, after passing the Report of the Council and the Accounts for 1959, the following Special Resolutions were unanimously adopted :

(i) THAT The Physical Society be voluntarily wound up and that Mr. Ernest William Coleman of Messrs. Knox, Cropper and Gedge & Co., Spencer House, South Place, London, E.C.2, and Dr. Alice Christine Stickland, 1 Lowther Gardens, London, S.W.7, be appointed joint liquidators for the purposes of such winding up.

(ii) THAT in accordance with the powers contained in Clause 8 of the Society's Memorandum of Association all surplus assets after the discharge of the Society's liabilities be transferred to The Institute of Physics and The Physical Society to form part of the Physics Trust Fund.

Salary Survey

There has been an extremely good response (better than on any previous occasion) to the request for data relating to members' emoluments. A report is being prepared and will be published in either the September or October *Bulletin*.

Graduateship examination

The number of candidates for the Graduateship examination continues to increase. This year 195 candidates sat, of whom 64 passed. The names of successful candidates and the question papers will be published in the September *Bulletin*.

Qualifications for membership

At its July meeting the Council approved recommended changes in the lists of academic qualifications accepted for the regulations relating to Graduateship, Associateship and Fellowship of the Institute, and also agreed the conditions for admission of Fellows of The Physical Society. Full details of these will appear in the September *Bulletin*.

World Directory of Crystallographers

The *World Directory of Crystallographers* to be published by the International Union of Crystallography will soon be available for distribution.

Members who would like a copy at the reduced rate of 8s. 6d. should send their orders with remittances to the Secretary of the Institute and Society as soon as possible.

A Symposium on Automatic Control

A Symposium on Automatic Control sponsored by The British Conference on Automation and Computation and arranged by The Institution of Mechanical Engineers will be held in London on September 27 and 28, 1960.

Further details are available from the Secretary of The Institution of Mechanical Engineers, 1 Birdcage Walk, Westminster, S.W.1.

Autumn Meeting on Ion Sources

The Electronics Group has arranged a meeting to consider recent developments relating to ion sources, to be held at 47 Belgrave Square, at 10.30 a.m. on Friday, September 30. Subjects to be treated include r/f sources, positive ions, negative ions, and appropriate fundamental processes. Offers of contributions will be considered by the committee and should be sent to Dr. C. A. Hogarth, F.Inst.P., Brunel College of Technology, Acton.

Reviews of Books

THE THEORY OF SPACE, TIME AND GRAVITATION

By V. Fock, translated by N. Kemmer

London: Pergamon Press. Pp. xviii + 411. Price 100s.

That Professor Fock's considered views on a subject to which he has himself contributed so much are now available in English is of great importance to all who are interested in the foundations of physics. This book has been put into excellent English by Professor Kemmer, who contributes a highly appreciative preface. The advanced level of both content and price make it doubtful if the book can be widely used by undergraduates, but it is an essential reference for postgraduate workers in fundamental theory.

The argument of this work follows a natural order; special theory of relativity, repeated and extended in tensor form, tensor analysis, principles of gravitation theory, soluble problems in gravitation theory, succeed each other in a beautifully lucid exposition. Fock's basic view-point does not coincide with that of Einstein: he rejects the adjective " special " for the theory of relativity covered by the Lorentz transformation, believing that the term " general relativity " is invalid. Thus Fock rejects the principle of equivalence of gravitational field and accelerated reference system, since this equivalence is both local and approximate, and bases gravitation theory on the equality of inertial and gravitational mass, with the hypothesis that space and time possess a Riemannian metric.

Most of the problems solved in the book relate to an " isolated system " of bodies, and the gravitational equations are solved subject to the boundary conditions of Galilean space-time at large distances and of outgoing radiation. Sections 94 and 95 give a brief development of the theory of Friedmann-Lobachevsky space and of the red shift, but in the absence of any theory of local non-uniformities in this space Professor Fock refrains from cosmological speculation, and indeed his brief dismissal of the Mach problem seems to misrepresent this essentially cosmological question as a mere error in discussing the " isolated system " in Fock's own sense. This attitude may stem from Fock's avowed philosophical debt to Lenin's *Materialism and Empirio-criticism*, a polemic opposing Marxist materialist philosophy to confused views expressed by Mach among others; however that may be, the richness of the present work in its well defined field compensates for the absence of cosmological discussion.

Readers of the *Bulletin* will find special pleasure in the discussions of the local equivalence of fields of acceleration and gravitation, and of the clock paradox, in sections 61 and 62. The clock paradox is elucidated in the solution of one problem, where the travelling clock is a projectile in a gravitational field which is zero in one region and uniform in another. The difference in time between the travelling clock and that at rest turns out to depend, even in sign, on the fraction of the time of motion spent under acceleration. The clocks agree at the moment of return if the time of deceleration is three quarters of the time of flight, and differ by the amount the special theory predicts if the time of deceleration is negligible.

This will be a standard work on gravitational theory for a long time to come.

G. WYLLIE.

THE CONCEPTS AND THEORIES OF MODERN PHYSICS

By J. B. Stallo

London: Oxford University Press. Pp. xxix + 325. Price 38s.

A reader might well be pardoned if, on seeing the title of this book (and even if he looked inside) he thought that he had before him a contemporary work on theoretical physics. In fact, the author—a German with an old Frisian name—was born in 1823 and died in 1900. He emigrated to the United States as a youth, and produced the substance of the present volume in 1886, corresponding to the third American Edition. We now have the advantage of an illuminating introduction by Professor Emeritus P. W. Bridgman. Stallo must have been an interesting character; part of his life was spent as a jurist and part as a diplomat. He resembles a mixture of Leibnitz and Boole on a small scale: Leibnitz because of his universality, and Boole on account of his clarity. But there the parallel ends, for Stallo was no mathematician. His book would indeed be a classic if he were. He lived in an exciting period, and made the best of it. Clearly, he was an intellectual missionary, a thinker well in advance of his time, and a beneficent influence.

The author says quite simply that he is making a contribution to the theory of cognition, not to that of physics or metaphysics. How does this square with his title ? Stallo was not unnaturally misrepresented by some of his reviewers : what is accomplished in these pages is an extremely able discussion of the fundamentals of nineteenth century physics from the point of view of the theory of cognition. Put like that, his position is somewhat clarified.

All the great names one would expect appear in the index, with the exception of Willard Gibbs. This seems odd, since Stallo was much concerned with the principles of thermodynamics. But two points are of deep significance. One is that he found the (then current) explanation of specific heats wholly unsatisfactory, and the other that the complexity of molecular spectra did not fit into the picture at all. Thus, he had picked out just the two phenomena (close-coupled as they are), so prominent in the early triumphs of the quantum theory. This represents no small achievement in foresight, and accords Stallo a seat of honour among the seers. He might almost have anticipated Nernst's theorem in the same way. Professor Bridgman however places his finger upon the weak spot. Stallo had a rather naïve faith in logic, in the sense that if something is logically incorrect it cannot lead to results which are correct in physics. This is an old dilemma, and comes from forgetting that *natural* philosophy only

uses part of the whole theoretical edifice. Words are one thing, action is another. But it has taken the new three-valued logic to cope with physics in the mid-twentieth century.

Stallo was not a precursor of the Vienna Circle, but he did good in relegating " models " to their proper place. Anaxagoras had greater insight than Stallo as to how the world could have been made, but the latter has well earned our gratitude for his ruthless attack on mental fictions, and their manifold disguises.

F. I. G. Rawlins.

A DEGREE PHYSICS — PART III : OPTICS

By C. J. Smith

London : Edward Arnold (Publishers) Ltd. Pp. vii + 736. Price 63s.

This is a new volume in the series entitled " Degree Physics " and treats the subject at a somewhat higher standard than usually expected of general degree students. It will commend itself to those experienced in the teaching of Optics because in it they will find their especial interests well discussed, and to those less experienced, because it will inform them upon many points often inadequately emphasized in other texts. The treatment is neither so advanced nor so detailed as to be unsuitable for students of average ability. The discussions are admirably clear though occasionally the notation seems a little cumbersome, as for instance when the use of dashes as well as suffixes somewhat mars the elegant treatment of angular magnification by a prism and the explanation of Schuster's method of adjusting a spectrometer (a treatment delightful to welcome in print for until now the reviewer had met it only in his own laboratory).

The first chapter of the book deals with mathematical description of vibrations, the second with determination of the speed of light including recent methods ; then follow fourteen chapters on geometrical optics, light sources and photometry. The chapter on lens aberrations, treats of astigmatism and spherical aberration of single surfaces and thin lenses in some detail. It is a pity that there is no mention of the fact that the total spherical aberration of two lenses of opposite powers can be reduced to zero by suitable choice of curvatures. This omission does nothing to correct the belief held by so many students that the design of a doublet lens is solely concerned with achromatism.

Chapter 17 treats of colour, and is followed by six chapters on physical optics. The treatment is much to be recommended, although the reviewer is sorry to note that the necessity for the use of half shadow devices in polarimetry is ascribed to the presence of scattered light and to the difficulty that " the observer is called upon to memorize conditions in the field of view as the analyzer is slowly rotated." Reference to the Weber-Fechner law of response of the eye to a light stimulus, which is nowhere mentioned, would have provided convincing argument both for the need for a half-shadow device, and for the restriction of its use to angles greater than a degree or two. But where so much of the book is so good criticism seems merely carping. The book is well produced, well printed, and the diagrams are beautifully clear. Students and teachers alike will find themselves indebted to Dr. Smith.

A. M. Taylor.

THE THEORY OF FUNCTIONS OF REAL VARIABLES

By J. Pierpont

New York: Dover Publications Inc. Vol. I. Pp. xii + 560. Price $2.45. Vol. II. Pp. xiii + 645. Price $2.45

FUNCTIONS OF A COMPLEX VARIABLE

By J. Pierpont

New York: Dover Publications Inc. Pp. xiv + 583. Price $2.45.

We have here in the well known Dover series, reprints of books which have been in use for a very long time. Vol. I on the real variable was first published in 1905, Vol. II in 1912 and the complex variable in 1914. The fact that they are still considered worth reprinting, in spite of the many books which have appeared since then, is in itself sufficient testimony to their value.

A fair knowledge of the processes and methods of the calculus is assumed, and the aim of these books is to examine carefully the conditions under which the theorems of the calculus are correct and to extend as far as possible or useful the limits of their validity.

Vol. I deals, from this point of view, with the fundamental processes of differentiation and integration and related topics. Vol. II continues with improper multiple integrals, infinite series and products, theory of measure and Lebesgue integrals, Fourier series, curves, including Jordan's theorem, and surfaces.

The volume on complex variable is quite separate from the others and includes chapters on real term series and on differentiation and integration of functions of real variables before differentiation and integration on the complex plane. The elementary functions are dealt with quite fully. There is a section on asymptotic expansions, after the general theory of analytic functions. Three chapters deal with elliptic functions, and the last three chapters with linear differential equations, spherical harmonics, and Bessel and Lame functions.

The absence of any discussion of Riemenn surfaces is mentioned in the preface, and one is rather surprised to find no mention of Contour integration, nor is there any reference to the theorem concerning the difference between the numbers of zeros and poles within a contour. These are omissions which could hardly occur in a modern book on the subject which claimed to cater for the applied mathematician. Despite this there is an enormous amount of useful mathematics in these three books.

A. W. Gillies.

News of Members

FELLOWS

T. E. Allibone was awarded the C.B.E. in the Birthday Honours List.

G. Black is Technical Manager of the Central Technical Services, Research and Development Branch of the Development and Engineering Group of the U.K.A.E.A. at Risley.

W. N. Christiansen is Professor of Electrical Engineering in the University of Sidney.

R. J. Clayton was awarded the O.B.E. in the Birthday Honours List.

E. G. Cox has now taken up his appointment as Secretary of the Agricultural Research Council.

P. J. Duncton has been appointed Director and General Manager of Fairey Engineering Limited, Heston, Middlesex.

W. F. Floyd has been appointed Head of the new Department of Ergonomics and Cybernetics at Loughborough College of Technology, the first department of its kind in this country.

D. H. Follett is now Director of the Science Museum, London.

M. E. Haine is Director of the A.E.I. Research Laboratory, Harlow, Essex.

L. G. H. Huxley has been appointed Vice-Chancellor of the Australian National University, Canberra.

E. R. Johnson is a Principal Officer in the Aerodynamics Division of the Weapons Research Establishment, Adelaide, South Australia.

J. H. Martin is Manager of Health and Safety at the Chapelcross Works of the U.K.A.E.A.

A. F. Pearce is now Senior Research Physicist in the Electrical Engineering Department of the Imperial College of Science and Technology, London.

E. G. Steward has been appointed Reader in Physics at Northampton College of Advanced Technology, London.

J. Taylor (*Honorary Treasurer*), a Director of Imperial Chemical Industries Ltd., has also been appointed Chairman of Almin Ltd.

E. J. Whitmore is now Product Development Manager of Sylvania Electric Products Inc. (Special Tube Operation), of Williamsport, Pennsylvania, U.S.A.

ASSOCIATES

R. K. Angus has been appointed a Lecturer in Physics at Rugby College of Engineering Technology.

D. G. Avery is now in Washington as the Senior Representative of the U.K.A.E.A. in the United States.

D. S. Beard has been appointed Manager of the Special Products Division of Griffin and George Ltd.

J. Bennett is the Technical Sales Manager of Leybold Vacuum Sales Ltd.

R. F. Blackwell is now at the Berkeley Nuclear Power Station, Glos.

J. L. W. Churchill has been appointed Chief Engineer of the Process Components Department, A.E.I. Ltd., Instrumentation Division.

R. Cockburn received the K.B.E. in the Birthday Honours List.

E. W. Dickson is a Research Physicist with Associated Engineering Ltd., Leamington Spa.

N. J. Dunning has been appointed a Lecturer in Physics at the University of Manchester.

F. J. Glen Earl has taken up an educational post with Unesco in Beirut, Lebanon.

A. Garnham has been appointed Senior Lecturer in Physics in the University of Durham.

D. W. Hadley is with the Research Dept. of I.C.I. Fibres Division, Harrogate.

R. V. Harrowell is a Physicist with the Central Electricity Generating Board.

G. H. B. Haskard is Head of the Mathematics, Physics and Navigation Department of The South Australia Institute of Technology, Adelaide.

R. Hayes has joined the staff of the British Hydrocarbon Chemicals Ltd.

G. R. Higson is with the Mining Research Establishment of the National Coal Board at Isleworth.

M. J. Hill is now with the Central Electricity Generating Board.

J. K. Jones is Senior Health Physicist in the Nuclear Health and Safety Department of the Central Electricity Generating Board.

C. G. McCue is a Senior Scientific Officer at the Weapons Research Establishment at Salisbury, South Australia.

D. M. Mackay is now a Lecturer in Physics at the University College of North Staffordshire.

J. Mahanty will be joining the Government of India Atomic Energy Establishment, Bombay, in October.

G. Maidanik is Senior Scientist with Bolt Beranek and Newman Inc., Cambridge, Massachusetts.

D. M. J. P. Manley is an Engineer with the British Broadcasting Corporation, in the Acoustic Research Section.

J. H. Mason has joined A.E.I. Research Laboratory, Harlow, as a Senior Physicist.

E. W. J. Mitchell has been appointed Reader in Physics at the University of Reading.

J. P. Morrison has become Manager of a Programming Systems Division of Aircraft-Marine Products (Great Britain) Ltd., Glasgow.

F. J. Pearson has been appointed Head of the Applied Physics Department of the Lanchester College of Technology, Coventry.

H. Rose is now Chief Physicist at the Nuclear Research Centre of C. A. Parsons & Co. Ltd., Newcastle-upon-Tyne.

H. C. Singh has been appointed Principal of Vishvakarma Institute of Engineering Technology, Ludhiana, India.

W. E. Smith is on the staff of the Department of Applied Mathematics of the University of New South Wales, Sydney, Australia.

G. Thomas is an Instrument Engineer in the Plastics Division of I.C.I. at the Hillhouse Factory, Lancs.

B. J. Thompson has been appointed a Lecturer of Physics at the University of Leeds.

B. A. Tozer has joined the staff of the Central Electricity Research Laboratory, Leatherhead.

D. T. Turnbull has been appointed Head of the Physics Department at Rutherford College of Technology, Newcastle-upon-Tyne.

E. E. Welch has joined the Research and Development Department of the Central Electricity Generating Board.

R. A. Wilson has been appointed Chief Education Officer in Malacca, Malaya.

GRADUATES

G. P. Barlow is now Assistant Lecturer in the Medway College of Technology, Chatham.

W. G. Buckley has been appointed Head of the Physics Department of Wallasey Grammar School.

B. F. D. Cassidy has been commissioned in the Instructor Branch of the Royal Navy.

A. V. Evershed has been appointed a Lecturer at the Croydon Technical College.

J. Glazer has joined E. K. Cole Ltd., Southend-on-Sea, as a Project Engineer.

H. Herbert is an Experimental Officer at the Royal Aircraft Establishment, Farnborough.

J. B. Herron is Physics Master at Edinburgh Academy.

I. G. Hood is now with Babcock and Wilcox Ltd., at Renfrew.

C. S. Hope is a Physicist in the Regional Physics Department of the Western Regional Hospital Board, Glasgow.

M. J. McAllister has been appointed a Lecturer in Physics in the Liverpool College of Building.

R. C. Maddison has joined the staff of the Research Laboratory of A.E.I. Ltd., Rugby.

R. J. Mears is a Research Physicist at the Central Electricity Research Laboratories at Leatherhead.

L. R. A. Melton is at the Electronics Factory of A.E.I. (Rugby) Ltd., Leicester.

J. L. Morgan is a Physicist in the Nuffield Research Centre of the British Motor Corporation.

A. S. Morrison is now an Assistant Lecturer in the Physics Department of Coventry Technical College.

M. J. Shadbolt has joined the staff of the British Scientific Instrument Research Association at Chislehurst.

J. Springate is now teaching at the John Neilson Institute, Paisley.

D. A. Taylor has joined Allmanna Svenska Electriska Aktiebolaget at Ludvika, Sweden.

The Register

ELECTIONS TO MEMBERSHIP

THE FOLLOWING ELECTIONS WERE MADE BY THE BOARD ON JUNE 22, 1960

An asterisk (*) indicates transfer from another grade

FELLOWS (10)

*Dutton, Jack, B.Sc., Ph.D., Lecturer, University College of Swansea, Singleton Park, Swansea.

Dyson, James, B.A., Consultant (Optics), Associated Electrical Industries Research Laboratory, Aldermaston Court, Aldermaston, Berks.

*Franks, Albert, B.Sc., Ph.D., Senior Scientific Officer, National Physical Laboratory, Teddington, Middlesex.

*Hamilton, Robert John, B.Sc., Scientist, National Coal Board, Central Research Establishment, Stoke Orchard.

*Jones, Edgar William, B.Sc., Physicist, Elliott Automation Systems Ltd.

*Ramm, Colin Arnold, M.Sc., Ph.D., Group Leader, C.E.R.N., Geneva, Switzerland.

Steckelmacher, Walter, B.Sc., Head of Instrument Research Division, Edwards High Vacuum Ltd., Crawley, Sussex.

Tomlin, Stanley Gordon, B.Sc., Ph.D., Reader in Physics, University of Adelaide, Australia.

*Tyler, Frank, B.Sc., Ph.D., Deputy Headmaster-Senior Science Master, Queen Elizabeth Grammar School, Blackburn, Lancs.

Williams, Gwilym Iorwerth, B.Sc., Ph.D., Head of Physics Section, Fulmer Research Institute Ltd., Stoke Poges, Bucks.

ASSOCIATES (54)

*Armstrong, Wallace Elliott, M.Sc., Physicist, Wellington Hospital Board, New Zealand.

*Baker, Thomas Henry Brian, B.A., Scientific Staff, Research Laboratory, Associated Electrical Industries (Rugby) Ltd., Rugby, Warwickshire.

Bayes, David Dexter, B.Sc., Assistant Lecturer, Brighton Technical College.

Birch, Collinson, B.Sc., Research Physicist, C. A. Parsons & Co. Ltd., Newcastle-upon-Tyne, Durham.

*Bowling, Alan, B.Sc., Senior Supervisor, Associated Electrical Industries (Manchester) Ltd., Trafford Park, Manchester.

*Buckingham, Herbert Charles, B.Sc., Senior Physicist, Quasi-Arc Ltd., Birmingham.

Bullock, Gordon, M.Sc., Ph.D., Nuclear Power Department, A.S.E.A., Sweden.

Burns, Desmond Malone, B.Sc., Ph.D., Lecturer, Queen's College, University of St. Andrews.

*Burdett, Eric Wilfred, B.Sc., Lecturer, Norwich City College.

Canning, George William, B.Sc., Senior Lecturer, Goldsmiths' College, University of London.

*Christie, David George, B.Sc., Head of Physics Division, Aluminium Laboratories Ltd., Banbury, Oxon.

Clark, Michael David, M.Sc., Leader, Radiation Physics Group, Atomic Power Constructions Ltd., London.

Coen, Ernesto, D.Phil., Research Physicist, Pilkington Brothers Ltd., St. Helens, Lancs.

Collins, Robert, B.A., B.Sc., Senior Physicist, The Nuclear Power Group, Knutsford, Cheshire.

*Dean, Thomas James, B.Sc., Ph.D., Research Physicist, G.V. Planer Ltd., Sunbury-on-Thames, Middlesex.

*De Vere, Raymond Harold, M.Sc., Scientist, National Coal Board, Stoke Orchard, Gloucestershire.

Forrest, Joseph Graham, M.A., Lecturer, Paisley Technical College, Renfrewshire.

*Forsyth, John Bruce, M.A., Ph.D., Research Assistant, Cavendish Laboratory, Cambridge.

*Frost, Henry George, B.Sc., Staff Lecturer, Department of Extra-Mural Studies, University of London.

Gardner, Frank, B.Sc., Section Leader, Plessey Nucleonics, Northampton.

Glass, Harold Izak, B.A., Senior Physicist, Western Regional Hospital Board, Regional Physics Department, Glasgow.

*Gooberman, George Lancelot, B.Sc., Ph.D., Lecturer, Department of Electrical Engineering, Royal Technical College, Salford, Lancs.

*Green, Arthur, B.Sc., Ph.D., Physicist, The General Electric Co. Ltd., Wembley, Middlesex.

*Haddock, William, M.A., Scientific Staff, The General Electric Co. Ltd., Applied Electronics Laboratories, Stanmore, Middlesex.

*Hidden, Nicholas John, B.Sc., Research Assistant, Birkbeck College, London.

*Holister, Geoffrey Stanley, M.Sc., Research Physicist, Budd Instruments Division, Pennsylvania, U.S.A.

*Joy, Alan Roderick, Senior Physicist, Oldchurch Hospital, Romford, Essex.

*Lewin, Douglas William, Electronic Engineer, Marconi Research Laboratories, Gt. Baddow, Essex.

*Lill, Geoffrey David, B.Sc., Ph.D., Ore Dressing Engineer, United Steel Companies Ltd., Rotherham Yorks.

Loughhead, Ralph Edwin, M.Sc., Research Officer, C.S.I.R.O., National Standards Laboratory, Sydney, Australia.

*Miller, Vincent, M.Sc., Technical Officer, Imperial Chemical Industries Ltd., Dyestuffs Division, Blackley, Manchester.

*Moorhead, Thomas Peter, B.Sc., Senior Experimental Officer, Atomic Energy Research Establishment, Harwell, Didcot, Berks.

Morley, Keith Alan, B.Sc., Ph.D., Health Physicist, Nuclear Power Group, Knutsford, Cheshire.

*Parmee, John Llewellin, B.Sc., Research Laboratory Staff, Associated Electrical Industries (Rugby) Ltd., Rugby, Warks.

*Putner, Tony Ian, Research Physicist, Edwards High Vacuum Ltd., Crawley, Sussex.

Rees, Ruth Mary, B.Sc., Head of Science Dept., King Egbert Technical School, Sheffield.

Richards, Edward Alexander, B.Sc., Experimental Officer, Signals Research and Development Establishment, Christchurch, Hants.

Richmond, Peter Edward, B.Sc., Senior Science Master, Hayes Grammar School, Middlesex.

*Rogers, Peter Oliver, B.Sc., Head of Instruments Section, Esso Research Ltd., Abingdon, Berks.

Salter, Wallace, B.Sc., Senior Physics Master, Queen Elizabeth's Grammar School for Boys, Mansfield, Notts.

Schlapp, Donald Michael, B.A., Ph.D., Lecturer in Physics, University College of North Staffordshire, Keele, Staffs.

*Shuttleworth, Eric, B.Sc., Senior Physicist, St. Bartholomew's Hospital, London.

Silverston, Derek Anthony, B.Sc., Ph.D., Senior Lecturer, Royal Naval College, Dartmouth.

Thompson, John Ronald, B.Sc., Head of Physics Department, Cockburn High School, Leeds.

*Tipping, Frederick Robert, Head of Instrument Department, Mullard Magnetic Components, Crossens, Southport, Lancs.

*Turner, Stanley, B.Sc., Technical Officer, Imperial Chemical Industries Ltd. (Plastics Division), Welwyn Garden City, Herts.

Wallis, Arthur Leslie, B.Sc., Shift Manager, U.K. Atomic Energy Authority, Capenhurst.

Warburton, Joseph Aubrey, B.Sc., Laboratory Manager-Lecturer, University of Queensland, Australia.

Ward, Geoffrey Marcus, B.Sc., Engineer, Atomic Weapons Research Establishment, Aldermaston, Berks.

Wheeler, Ernest John, M.Sc., Lecturer, Brunel College of Technology, London.

*Whiting, Kenneth Brian, B.Sc., The Scientific Staff, The General Electric Co. Ltd., Stanmore, Middlesex.

Wilkinson, William Thomas, B.Sc., Senior Scientific Officer, British Ceramic Research Association, Stoke-on-Trent, Staffs.

*Williams, Paul Randall, B.Sc., Ph.D., Physicist, National Hydrogen Bubble Chamber Project, University of Liverpool.

Williams, Royson Vaughan, M.Sc., M.A., Research Physicist, Associated Electrical Industries Ltd., Aldermaston Court, Aldermaston, Berks.

GRADUATES (34)

*Alderson, John Edward Arthur, M.Sc., Postgraduate Student, University of Western Australia.

Ashton, John, B.Sc., Physicist, U.K. Atomic Energy Authority, Springfield Works, Nr. Preston, Lancs.

Backler, Leonard Ronald Henry, B.Sc., Engineer (Optical Section), Ministry of Aviation.

Baker, Sidney John, B.Sc., Development Engineer, Ferranti Ltd., Manchester.

Cattermole, Michael John George, B.Sc., Research Physicist, Cambridge Instrument Company, Cambridge.

Cooper, Martyn John, B.A., Research Student, Cavendish Laboratory, Cambridge.

Dawson, George Albert, B.A., Research Student, University College of North Staffordshire, Keele, Staffs.

Delbridge, Robert Francis, B.Sc., Technical Assistant, Abel and Imray, Chartered Patent Agents, London.

Ferguson, John Murray, B.Sc., Semiconductor Development Engineer, Standard Telephones and Cables Ltd., Footscray, Kent.

Goddard, Antony John Hudson, B.Sc., Research Student, Imperial College, London.

Gilbert, Norman Richard, B.Sc., Assistant Experimental Officer, Royal Radar Establishment, Malvern, Worcs.

Hall, Martin Peter Maurice, B.Sc., Assistant Experimental Officer, Radio Research Station (D.S.I.R.), Slough, Bucks.

Hastilow, Patrick Arthur Paul, B.A., Research Student, University College of North Staffordshire, Keele, Staffs.

Hearn, John Robert, B.Sc., Technical Assistant, de Havilland Engine Co. Ltd., Edgware, Middlesex.

Hill, Graham John, B.Sc., Research Student, University of Bristol.

Hinson, James Denis, B.Sc., Junior Engineer, Hunting Engineering Ltd., Beds.

*Jones, Robert Peter, B.Sc., Research Student, University College of North Staffordshire, Keele, Staffs.

Jory, Rodney Leonard, B.Sc., Research Student, University of Adelaide, Australia.

King, James Newington, B.Sc., A.R.C.S., Research Student, Imperial College, London.

*Lawrence, Michael Newman, Dip.Tech., Research Scientist, Gas Council Midlands Research Station, Wharf Lane, Solihull.

Le Marne, Alan Ernest, B.Sc., Lecturer in Physics and Mathematics, University of New South Wales, Australia.

Lever, Allan Martin, M.A., Assistant Editor, " Physics Abstracts," Institution of Electrical Engineers, London.

Littlewood, George, B.Sc., Experimental Officer, U.K. Atomic Energy Authority, Springfield Works, Nr. Preston, Lancs.

Maclaren, Hugh McCallum, M.A., Assistant Science Teacher, Dalkeith High School, Dalkeith, Midlothian.

Nicholson, James Stewart, B.Sc., Assessment Engineer, The General Electric Co. Ltd., Applied Electronics Laboratories, Stanmore, Middlesex.

Smith, David, B.A., Research Student, University College of North Staffordshire, Keele, Staffs.

Stewart, James, A.R.C.S.T., Assistant Teacher of Science, Eastbank Academy, Glasgow.

Thornley, Richard Frank Maute, B.A., Research Student, University of Cambridge.

Trudgill, Alan Michael, B.Sc., Development Engineer, Mullard Radio Valve Co. Ltd., Mitcham, Surrey.

Thomson, Graham Low, B.Sc., Technical Assistant, U.K. Atomic Energy Authority, Chapelcross Works, Dumfriesshire.

Wain, George William, B.Sc., Assistant Master, Heckmondwike Grammar School, Yorks.

Woodall, Geoffrey, B.Sc., Graduate Apprentice Electrical Engineer, Electro-Automat Ltd., Swinton, Manchester.

Woodhouse, Graham, B.Sc., Postgraduate Student, Department of Fuel Technology, University of Sheffield.

Wright, Maurice Henry, B.Sc., Graduate Apprentice, Mullard Radio Valve Co. Ltd., Mitcham, Surrey.

Twenty-four Students and four Subscribers were also admitted.

The Institute's Journals

PRINCIPAL CONTENTS OF THE AUGUST, 1960, ISSUES

British Journal of Applied Physics : Volume 11, No. 8

CONFERENCE REPORT

Summarized proceedings of a conference on some aspects of magnetism, Sheffield, September, 1959. By R. S. Tebble and D. E. G. Williams.

The report describes the proceedings of a conference on magnetism held at Sheffield University by The Institute of Physics in September 1959. The subjects discussed at the five sessions and reported in the article came under the headings (i) The behaviour of ferrites and some alloys ; (ii) Domain effects and thin films ; (iii) Domains ; (iv) Neutron diffraction ; (v) Permanent magnetic materials.

Gaseous diffusion in porous media : Part 1.—A non-steady state method. By J. A. Currie.

Laboratory equipment, capable of modification for use on soils in the field, was constructed to study diffusion in porous systems. A simple katharometer employs the exposed element of a thermal milliammeter to measure the instantaneous composition of hydrogen/air mixtures ; the most convenient working condition is when 15mW are dissipated in the hot wire, at which the thermocouple output changes from 0·5mV in pure hydrogen to 2·5mV in air. The geometry of the experimental system is simple enough to permit a standard solution of the non-steady state equation for interdiffusion of two gases to be applied, and, as a check on performance straight tubes of slightly varying geometry were used to measure the diffusion coefficient of hydrogen into air, and its dependence on temperature. Reproducibility was very good and, within the limits of experimental error, the coefficient obtained was the same for 100% hydrogen into 100% air, and 60% air + 40% hydrogen into 100% air. Measurements at

12, 20, 28 and 36°C, fitted $D = D_0(T/273)^n$, with

$$D_0 = 0{\cdot}651 \text{ cm}^2 \text{ s}^{-1} \text{ at n.t.p.}$$

$$n = 1{\cdot}715$$

Standard values in the literature are $D_0 = 0{\cdot}611$ (International Critical Tables, 0·634 and 0·661 (Smithsonian Physical Tables). The latter reference gives $n = 1{\cdot}75$.

Gaseous diffusion in porous media : Part 2.—Dry granular materials. By J. A. Currie.

The diffusion of hydrogen through cylindrical samples of porous granular materials, 3 in. long and 2 in. diameter, was measured by the non-steady state technique of Part I, and reduced coefficients of diffusion D, referred to the value D_0 in free air, were calculated for over twenty materials with porosity ε between 0·18 and 0·98. Results are comparable with those obtained by other methods, and with those for analogous electrical properties of porous media. Replicate determinations on a given sample agree to within 1%, but larger differences, caused by variations in packing, are observed between duplicate samples of the same porosity. It is shown theoretically that $D/D_0 = (l/l_e)^2 f\varepsilon$, where f and l_e/l are factors for non-uniformity of cross-section and the increased length of the tortuous path followed by the gas, respectively. The influence on D/D_0 of not only porosity, but also particle shape, was clearly shown and there can therefore be no unique relationship for all materials, as often supposed, between diffusion rates and porosity. The equations of Burger and Bruggeman, both of which include a *particle* shape factor, were tested on the experimental data and neither was entirely satisfactory. An empirical equation of the form $D/D_0 = \gamma\varepsilon^\mu$ fits all materials where $\gamma(\leqslant 1)$ and $\mu(\geqslant 1)$ are constants for a specific type of granular material, and probably represent measures of *pore* shape. Two particle shape parameters, relative surface area and equivalent settling radius, were measured for a limited number of materials, but at best, only a general trend between these and the experimental values for the Bruggeman shape factor was observed.

Contact electrification of semiconductors. By W. R. Harper, F.Inst.P.

Recently published experimental findings on the electrification of rutile powder by sliding down a metal chute can be explained by an extension of the present author's theory of the separation electrification of metals. The mechanism of the electrification of insulators must, in most cases, be quite different.

Rolling-sphere viscometer for structured liquids. By G. W. Scott Blair, F.Inst.P., and J. C. Oosthuizen.

In the apparatus described, since the sphere is very small compared with the cylindrical tube containing the sample, fresh channels can be found for quite large numbers of tests. In this way measurements are made on hitherto unsheared material, and this is important in studying thixotropic or otherwise structured systems. The instrument may be used even when inertia effects are considerable since, over a wide range of experimental conditions, a very simple correction of the Oseen type is found to apply.

Relative viscosities of glycerine-water mixtures and of fat-free milks determined in the sphere viscometer agree adequately with those from an Ostwald or other capillary viscometer ; but the structure of renneted milk, even before rigidity sets in, is damaged by the drastic shearing and, for such systems, the rolling-sphere viscometer gives a more reliable picture of viscosity changes.

Observations of the magnetization reversal process in thin films of nickel-iron, using the Kerr magneto-optic effect. By M. Prutton.

Observations of the magnetization reversal process in uniaxial thin films of nickel-iron about 1500Å thick are reported. The experimental techniques used involve the comparison of measurements made in a Kerr magneto-optic apparatus, with the 400 c/s hysteresis loops taken with the pick-up loop both along and at right angles to the applied field. The results suggest that the magnetization reversal process in a film orientated with its easy axis at an oblique angle to the applied field occurs in three stages :

(i) coherent rotation until the angle is reached where a discontinuous jump in the orientation of the magnetization is expected to start ;

(ii) domain nucleation and growth from this angle to the angle where the jump should finish ;

(iii) coherent rotation until the magnetization lays along the field. The way in which some actual films differ from this model is discussed.

Skeleton strength and critical porosity in set sulphate plasters. By K. K. Schiller, F.Inst.P.

A theory dealing with the strength of porous brittle bodies which has been shown previously to apply to neat plasters is extended to cover sand bearing plasters. The sand grains have to be regarded as solid pores. The strength of sanded plasters is equal to that of the plaster matrix cementing the sand grains together. In spite of the increase of the characteristic parameters with sand content plasters are in practice the weaker the more sand they bear. This is because more water has to be added with respect to the plaster to obtain the desired consistency. The results are derived graphically from a special representation of the experimental results. Griffith's crack theory of brittle strength is shown to apply to the quality factor.

Calibration of manganese and gold foils for relative neutron flux measurements. By K. G. Stephens, A.Inst.P., and W. M. Cooper, Grad.Inst.P.

The usual method of intercalibrating foils for relative flux measurements, made by comparing the β^- activities of the foils after exposure to the same neutron flux, is compared with a method dependent on weighing the foils. The mass intercalibrations agree to within $\pm 1\%$ of the activity intercalibrations for gold and manganese foils in the range 90 to 100 mg/cm² thick, if a theoretical correction estimating the β^- absorption in the foil is applied to the measured mass values.

Interpretation of γ-ray scintillation spectra from fission-product mixtures. By D. H. Peirson, F.Inst.P.

γ-ray scintillation spectra are calculated for the products of simultaneous slow neutron fission of uranium 235. These theoretical spectra serve as a basis for comparison with practical measurement of fission-product mixtures. The variation with time, from 1 to 28 days, of the photo-electric peak height is shown for the prominent fission product activities. A rapid method of half-life analysis is described for use when peaks are inadequately resolved in energy. The effect of spectrometer resolution is discussed.

Measurement of crystallinity in drawn polyethylene terephthalate fibres by X-ray diffraction. By G. Farrow and D. Preston.

A method has been devised for the measurement of crystallinity in drawn fibres of polyethylene terephthalate fibre by an X-ray technique. Strictly monochromatic X-ray radiation is used and the X-ray camera is evacuated. This enables the photographic film, which is used to record the X-ray reflexion, to be free of " white " radiation and parasitic X-ray radiation normally termed " air scatter." The results show that the crystallinity in drawn yarns is much lower than expected and that no correlation exists between the crystallinity so measured and the density of the yarns.

The X-ray photographic method that has been developed is now comparable in speed with the alternative method of recording the X-ray diffraction pattern by means of a Geiger-Müller counter.

Variable ultrasonic water delay line. By G. W. Williams.

A variable delay line that uses ultrasonic propagation in water has been constructed. The delay, variable from 200 to 2600μs, is controlled by an input voltage, and is variable at a

rate of 40μs/s. A bandwidth of 800 kc/s is achieved at the carrier frequency of 7 Mc/s. The delay is stable to better than 0·05% over the normal range of room temperatures. Automatic gain control holds the change in level of the output pulse to better than ±1 dB.

Wall effect in the flow of lubricating greases in plunger viscometers. By A. D. Bramhall and J. F. Hutton, A.Inst.P.

In the plunger viscometer, grease is sheared between the surface of a long piston, or plunger, and the inner wall of a coaxial cylinder, the motion of the plunger being along the long axis of the cylinder. For some greases the flow curves depend on the width of the gap between the plunger and the cylinder, whilst for others the flow curves are independent of the gap width.

The results are best explained by postulating the existence of layers of softer grease adjacent to the viscometer walls with unmodified grease in between. For a given grease the layer thickness is independent of gap width. An analysis is presented which agrees with experimental results and permits the correction of the results to give a unique flow curve for the unmodified bulk grease. The magnitude of the correction shows a tendency to decrease with increasing roughness of the walls, with increasing viscosity of the base oil and with decreasing size of crystalline soap-fibre aggregates in the grease.

Application of photoelectric densitometry to the assessment of respirable dust samples. By A. R. Bugden, A.Inst.P., R. J. Hamilton, A.Inst.P., and G. H. S. Jones.

A technique has been developed for rapid assessment of the samples of respirable mine dusts obtained with the long-running thermal precipitator (NCB/MRE dust sampler type 101). The size segregation of particles in these dust samples enables the optical density of a thin strip across the deposit to be converted to the number of particles in that strip, the relationship being a function of mean particle size. The addition of a specially shaped weighting mask in the light beam enables a single measurement of the optical density of the whole deposit to be converted to the total number of particles, independently of the size distribution of the dust.

A densitometer has been devised and laboratory and field trials have established appropriate conversion factors from optical density to number of particles. The loss of light caused by the sample is measured over a small angle in order to reduce the difference between coal and the more transparent rock particles. For routine mine samples, which consist in general of mixed coal and rock, use of mean conversion factors is recommended.

Operation of the apparatus is simple and rapid, with accuracy and consistency comparable with microscope counting, and it is believed that a high proportion of the routine dust samples can be evaluated in this way. Further advantages of the technique are that it can be adapted, in conjunction with incineration, to the compositional analysis of dust samples and, by using appropriate conversion factors or weighting masks, to the measurement of the mass of dust in the samples.

Photoelectric method for the analysis of fluctuation records and its application to electrical noise. By J. Scott.

A photoelectric method is described for obtaining the after-effect function for a stationary-fluctuation process from a record in the form of a graph or oscillogram. The method is applied to the statistical analysis of some records of electric noise from various sources. Future possible developments of the method are indicated.

Effects of oil vapour contamination on the adhesion of zinc sulphide films to glass and silica. By L. Holland, F.Inst.P., and S. K. Bateman.

An investigation has been made of the effect of adsorbed oil molecules from diffusion pump fluids on the adhesion of zinc sulphide films to glass and evaporated silica substrates. Zinc sulphide films evaporated on to fresh coatings of silica in a silicone oil diffusion pump system readily peeled in a humid atmosphere, because the silica was contaminated by chemisorbed silicone molecules; silicones were not chemisorbed by glass covered by adsorbed water. Tests were made to find the time taken to cover a substrate surface with sorbed layers of different types of pump oil and thereby destroy the zinc sulphide film adhesion. A test oil was held in a water-cooled tray in the coating vessel and the specimen exposed to the non-saturated oil vapour for different periods before zinc sulphide deposition. Silica coatings held at 50°C could be exposed to Silicone 703 for 1 min, and Silicone 704 for 4 min, before the adhesion of the superimposed zinc sulphide deposit was badly impaired. Adsorbed molecules of Apiezon "C" did not unduly affect the adhesion of zinc sulphide films. With a silica layer at 230°C the formation time for a chemisorbed film of silicones was 75 min. Raising the temperature of the silica surface reduces the period for which silicone molecules linger and orientate themselves on the substrate. When glass is heated in silicone vapours in vacuum it gradually becomes covered with chemisorbed molecules as the OH-groups are removed, leaving the surface unshielded.

Explanation of the enhanced arc velocity on magnetic electrodes. By P. E. Secker.

When an arc moves between parallel horizontal metal electrodes, under the influence of the transverse magnetic field set up by current flow in the electrodes, the velocity/current characteristics may be separated into two groups, one comprising the magnetic and the other the non-magnetic materials. Calculations indicate that the enhanced velocity of the former group is due to a high-frequency skin effect near the rapidly moving cathode spot, such that the current paths are forced to the outer regions of the electrode, so increasing the transverse magnetic flux density in the critical region just outside the cathode.

Journal of Scientific Instruments : Volume 37, No. 8

Tomograph for industrial radiography. By D. Charles, Grad.Inst.P.

Tomography is a radiographic technique originally developed for medical purposes, in which relative movements of X-ray tube, subject and film are controlled so that a defined section of the subject is recorded as a sharp image, superimposed on a diffuse background due to blurred images of the rest of the subject. A tomograph for industrial use has been developed, and its capabilities assessed by tests on an assembly of wire mesh gauzes. Its practical application has been demonstrated with two types of heat exchangers, on which useful detailed observations were made. Tomography is considered to be particularly effective for examination of such assemblies in which repetitive detail is masked by overlying layers.

A 450J spark discharge for shadowgraph photography. By L. Whitlow.

To allow shadowgraph photographs to be taken of jet engines in altitude test cells, a 450J spark discharge is used. This emits sufficient light to illuminate a large working area and to allow armour plate and heat-resistant glass to be used for the cell windows. The design and construction of a suitable spark gap is given. The size of the light source is about 1mm diameter and the flash duration is 1·9μs. Details are also given of tests carried out on various insulating and electrode materials.

Moiré fringe reading head for use with a fine grating. By D. A. Palmer.

In the usual moiré fringe measuring system, practical difficul-

ties arise in the use of very fine gratings. An optical system is described in which the use of a separate index grating is avoided, the moiré fringes being formed between the scale grating and the image formed by its reflexion in a concave mirror. This arrangement has the particular advantage that the sensitivity is doubled. A working model has been constructed to demonstrate the principle.

Production of islands and dice in semiconductor slices with an ultrasonic drill. By R. D. Knight.
The production of islands of less than 0·002 in. in diameter with an ultrasonic drill is described along with the tools and the additions made to the equipment to achieve the degree of accuracy required. A novel feature is a frictionless gauge to indicate depth and rate of cutting. Also described is a method of bulk dicing and bulk islanding by the use of laminated tools. Each of these tools has a protruding "pilot-blade" to locate the work so that dicing can be correctly related to islanding and/or to any strip plating, markings, etc., put on the slice in earlier operations.
A novel self-aligning work table, essential to the bulk islanding process, ensures that the exposed face of the semiconductor slice is in intimate contact with the tool face.

Single tube sedimentation apparatus for the measurement of particle size distribution. By J. Kobak and D. J. Loveridge.
The equipment described is of the "liquid column with sediment extraction" type which enables dilute suspensions, 0·05%, solids concentration by volume, to be used. Thus the sedimenting conditions approximate to those required for unhindered settling of the particles. The apparatus is simple in design and does not require any specialized skills in its operation; one operator can easily control two sizings. Two similar sedimentation tubes have been shown to be devoid of individual characteristics and to be capable of giving reproducible results. The results compared well with those obtained in other laboratories using different sedimentation methods.

Multipoint digital temperature recorder with punched tape output. By T. S. Holden.
A sixty-five point potentiometric recorder, which gives its output in binary form on punched tape directly suitable for use with a digital computer, is described. The instrument operates intermittently, and provides reference times and parity and logical sum checks with the other data on the output tape. Although designed for recording temperatures, the instrument may be readily adapted to other applications.

High vacuum high temperature X-ray camera. By B. A. Hatt, P. J. C. Kent and G. I. Williams.
A camera suitable for the examination of reactive metals such as titanium and zirconium up to temperatures of 1000°C in a vacuum better than 1×10^{-6} mm mercury is described.
The high vacuum is obtained by constructing the camera in glass without demountable seals, and the use of a radiant heater in place of a conventional furnace assembly.
Application of the camera to studying the $\beta \rightarrow \alpha$ transformation in Ti – Cr and Ti – Zr alloys is described.

Sensitive and simple integrator. By J. P. Funk.
A sensitive and simple battery-operated current integrator is described. It uses as sensing element a standard millivoltmeter or microammeter, the pointer position of which is sampled at regular intervals by electromechanical means, the required movement of a feeler then being converted into rotation of a counter. The integrator accepts signals of varying polarity and also indicates the extreme signal level during any chosen period. It is particularly suited for the integration of quantities such as daily totals of net or global radiation.

Accurate measurements of phase differences with the Babinet compensator. By P. Hariharan, A.Inst.P., and D. Sen.
A considerable increase in accuracy is possible in measurements of phase differences with a Babinet compensator by reflecting the beams emerging from the compensator back through it. The first part of this paper deals with a new system of fringes produced in this fashion, in which the intensity distribution undergoes a periodic modulation as the path difference introduced by the compensator is varied, while the second section shows how the Babinet compensator can be converted into a uniform-field compensator by reflecting the beams emerging from the compensator back through it. By using a suitable half-shade device with such an arrangement, readings can be repeated to a few ten-thousandths of a wavelength.

Some modifications to an oscilloscope camera, and the construction of a control unit. By M. H. Evans and G. Pierson.
A Langham-Thompson series 200 camera has been modified to provide facilities for printing frame numbers along the edge of the photographic film, and to give warning when the supply of film is exhausted. The camera is used in conjunction with a control circuit that can provide either fully automatic operation or photography of single sweeps that have been preselected manually.

Temperature regulator for close temperature control. By E. N. Herzberg.
The design and performance of an electronic temperature regulator for an analytical oven of special construction is described. Stable temperature control with a resettability of better than 1°C is obtained over the range of 150-550°C. Residual peak-to-peak temperature fluctuations in the oven are less than 0·015°C.

Time analyser using a crystal-controlled trochotron tube. By T. Dobrowolski and J. Walker, F.Inst.P.
A nine-channel timing system is described in which a crystal oscillator has its output switched by a starting signal and is then used to drive a beam-switching tube (Burroughs, type MO-10R). An accurate sequence of voltage impulses is thus produced and these operate conventional circuits which gate the signals to be timed. The accuracy of the system is discussed briefly.

The torsiometer—an instrument for the study of gels considered as elastic solids. By W. A. Southorn.
A new instrument has been developed for studying changes in development of structure in the weak hydrogels produced when natural rubber latex from *Hevea brazilensis* is coagulated. The instrument records on a chart the progressive changes in torque required to give a fixed small value of deformation in an annular sample. The machine can be used for gel systems other than rubber, and may therefore have applications in other fields. Results may be expressed directly as a modulus of rigidity for materials with properties approximating to those of an elastic solid. For visco-elastic materials the modulus is a complex function including viscosity components. The range of sensitivity of the instrument is from 1 to 100,000 dyn/cm^2.

Portable electrometer voltmeter. By W. E. K. Gibbs.
This paper describes a portable high impedance d.c. voltmeter for measuring voltages up to two volts at impedances of up to 10^{10} ohms. The accuracy attained is about 2% of full-scale deflexion and the short-term zero drift is also of this order.

Novel displacement detector and its application in a recording thermobalance. By J. C. Van der Breggen and H. J. Wouterlood.
A transducer has been developed to detect changes in position of a balance beam. Its operation is based upon a differential capacitor. Variations in capacitance are made to produce directly a d.c. voltage corresponding in sign to the sense of deflexion of the balance beam. The construction of the transducer is described, and its application in automatic apparatus for thermogravimetric analysis is illustrated by results obtained on the dehydration of copper sulphate and the decomposition of quinoline phosphomolybdate.
The sensitivity of the instrument can be varied in nine steps to give full-scale deflexions from 10 to 5000 mg. An accuracy of about 1·5 mg or 0·75% of full scale was obtained for the 200 mg range.

Ratiometer phase angle indicator. By K. L. Morphew.
The principle of the moving coil ratiometer is described together with the circuit used with it for phase angle measurement. The mode of operation, performance, adjustment, and calibration are given.

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